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Mechanical Properties of Jute Fiber Reinforced With Polyester Fiber

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Abstract
In the present study the composite material with significantly light weight has been prepared using Jute Fiber as reinforcement and Polyester resin binder to study its mechanical properties. The composites were prepared with maximum of 25% fiber volume by hand layup method with parallel and random orientation with 3 cm fiber length. It was observed that tensile strength 83.25 M Pa which is almost four times higher than those of the plain polyester respectively. The percent elongation was also found to have significantly higher as compared to plain polyester sheet and similar trend was observed for flexural and impact properties.
Keywords: *Jute Fiber, Polyester Resin, Reinforced Composite, Mechanical Properties*

I. Introduction

In almost all countries for the world, natural fibers are available, apart from farmed a fiber which needs cultivation and consumes lots of water to be used such as cotton. There are various natural fibers which can be grown with minimum of water and no care such as bast fibers like jute, flex, sisal and many more which can be used for industrial and technical purpose which will give value addition to these fibers. Recently, cellulosic products and wastes such as wood flour, wood chips rice and wheat straw has been used as fillers in polymers, primarily for cost effectiveness and for high volume applications. Conventionally composites were formulated using carbon fibers, glass fibers which provide good mechanical properties but they are expensive and use of non-biodegradable fibers which in turn hampered the environment as compared to plain plastic sheets which are with quit a moderate mechanical properties. Natural fibers are light in weight, cheap, abundant, renewable and bio-degradable compared to synthetic such as nylon glass and carbon fibers which are expensive and non-renewable. The performance of natural fibers depends on there percent cellulosic content. Many investigations have proved that the valuable products like thermoplastic composites, molded sheets and papers can be produced from the bio-fibers. Nowadays, natural fibres reinforced materials have gained extensively interests. In particularly, the use of natural fibre reinforced composites has continuously increased due to their low density, low cost and environmental friendliness. Moreover, these natural fibres are also helpful to reduce both the oil dependency and carbon dioxide emission. In the present study efforts are made to investigate possible applications jute fiber which has very little textile apparel value due to its stiffness. The jute fiber is selected due to it has good mechanical, thermal and acoustic properties which are very important as far as technical end applications are concerned. Almost 85% of the world jute cultivation in concentrated in the Ganges Delta, which is shared by Bangladesh and India. China also has a dominating place in jute cultivation. Unsaturated polyester resin has been chosen as the matrix material because it's relatively cheap, having low shrinkage and can be molded at room temperature. Using various volume fractions of jute were combined with unsaturated polyester resin to prepare fiber reinforced polyester composites and tested for their mechanical properties.

II. Materials and Methods

Jute fiber was obtained from Institute of Jute & Fiber Technology, Kolkata, India. The jute fiber with 1.4 tex fineness, tenacity of 45 gf/tex and elongation at break of 1.8%.

Fig. 1 Raw Jute Fiber

The unsaturated polyester resin of the grade ECMALON 4411 was purchased from Nazmi Chemicals Pvt. Ltd. Akola, Maharashtra, India. The resin has 1250 Kg/m^3 density, 500 cps viscosity at 25^{o}C and 33% monomer content.

Formulation and Testing of Composites

In the present study, hand layup technique was used to formulate the composite samples. The samples were prepared in the 25 × 25 CM size, to test the mechanical properties like, tensile strength, flexural strength, and impact strength. The density and volume fraction of fibers in a cured polyester resin matrix is calculated by a using the following relations and excel sheet was formatted for accurate calculations of the fiber and resin weight by volume fractions.

Fig. 2 Designed Excel Sheet for Calculations of Fiber and Resin Fraction

For the preparation of the composite samples a mould was prepared on glass sheet of 25 × 25 cm size with wooden strips. For the good surface finish and easy de-molding very light layer of PVA and wax was applied. A primary layer of resin was poured in the mold and fibers were laid and remaining resin was poured uniformly over fibers. The wet composites were then lightly compressed to squeeze out the excessive resin and air. Another glass sheet greased with PVA and wax is placed on the top and pressed with a pressure of 2 bars. 24 hours curing time was used to obtain an optimum composite hardness and shrinkage. Finally after the composites were fully dried they were separated off from the moulds. Finally the samples are trimmed for finishing. The samples are prepared variation of fiber % by using catalyst + accelerator by volume of resin each.

The raw jute fibres are pre-washed with distilled water to remove the surface dirt present in the fibers and then put in an oven at 100°c for drying until it gains a constant weight. The mercerization or alkali treatment is carried out by immersing the washed coir fibres in a 10 % sodium hydroxide aqueous solution for 3hrs at room temperature. It should be stirred occasionally and after that the fibres are taken out and washed in order to remove any absorbed alkali.

Total of 25 samples were prepared with following combinations and compared with Plain sheet of Unsaturated Polyester Resin Sheet, to study the effect fiber percentage on the mechanical properties of the composites. (CTR 2.15 means 2 cm fiber length and 15% fiber and 85% resin.)

Treated With NaOH	CTR 2.15	CTR 3.15	CTP 2.15	CTP 3.15	Untreated	CUR 2.15	CUR 3.15	CUP 2.15	CUP 3.15
	CTR 2.20	CTR 3.20	CTP 2.20	CTP 3.20		CUR 2.20	CUR 3.20	CUP 2.20	CUP 3.20
	CTR 2.25	CTR 3.25	CTP 2.25	CTP 3.25		CUR 2.25	CUR 3.25	CUP 2.25	CUP 3.25
	C- Coarse	F-Fine	T- Treated	U-		R- Random	P- Parallel		UPR
	UPR-Unsaturated Polyester Resin			Untreated					

Table 1 Formulation of Samples

Tensile and Flexural Testing

Tensile test Specimens were tested with ASTD D 638M to measure the tensile properties. The standard samples are 160×12.5×4 mm three tests were taken for each combination. The samples were tested at a cross-head speed of 0.5mm/min and strain was measured using an extensometer.

Three-point bend test were performed using ASTM D 790M test method, with the standard specimen size 110×12×4 mm three tests were taken for each composition. A Three-Point bend test was chosen because it requires less material for each test and eliminates the need to accurately determine centre point deflections with test equipment. The tensile strength and modulus as well as flexural strength and modulus were calculated.

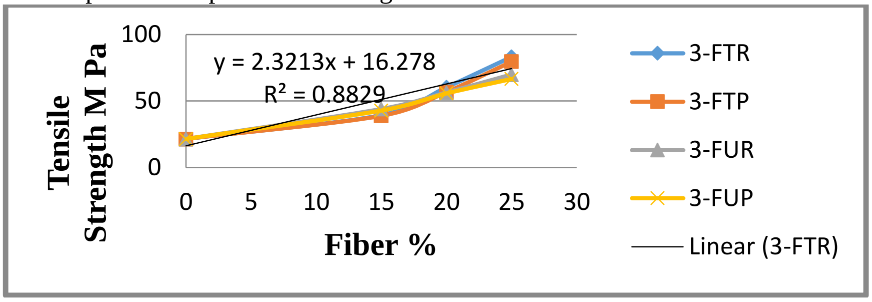
Impact Testing

The Izod Impact test specimens were manufactured according to ASTM D 256M to measure the impact strength 63.5×12.5×4 mm. A sharp file with included angle of 45° was drawn across the centre of the saw cut at 90 to the sample axis to obtain a consistent starter crack. The samples were fractured in a plastic impact testing machine and the impact toughness was calculated from the energy absorbed and the sample width.

III. Results and Discussion

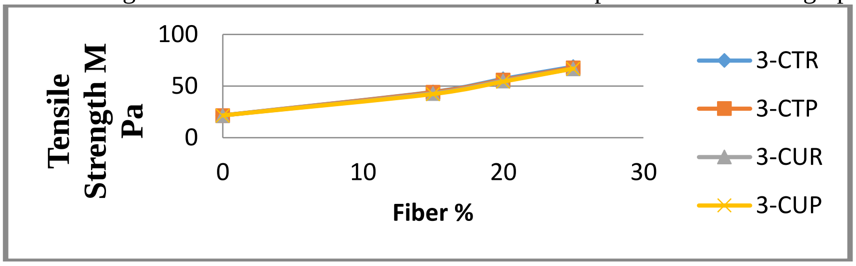
Tensile Strength

The mean tensile strength against volume fraction of fiber for the composite is shown in figure below it can be clearly seen that the tensile strength of the composites samples is increasing with fiber volume fraction.



Graph 1 - Mean Tensile Strength for Fine, 3cm Treated, Untreated, Random & Parallel Orientation of Fiber

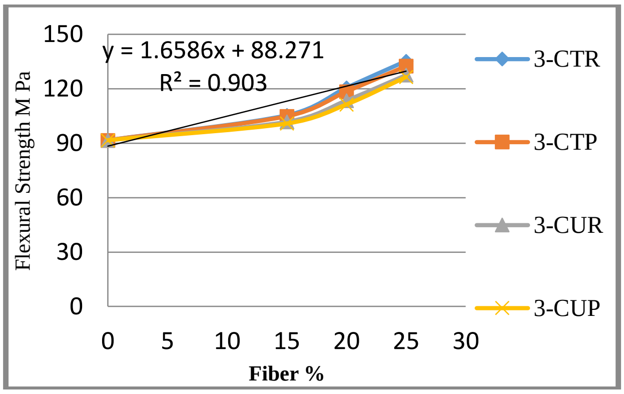
Composite sample with treated fiber, 3cm length and random orientation is having the highest tensile strength amongst all treated and untreated as shown in graph no. 1 as 83.24 M Pa which is 4 times better for 25 % fiber volume fraction, 3 times increase for 20 % fiber and almost double for 15% as compared to plain resin sheet which is 21.45 M Pa The similar trend has been observed in all the samples, the contribution of fiber volume to the tensile property is similar, the same trend can be seen and their no significant difference between the samples. The better strength in strength may be dedicated to the improved surface property and better bonding between fiber and resin. The r^2 value is represented in all the graphs.



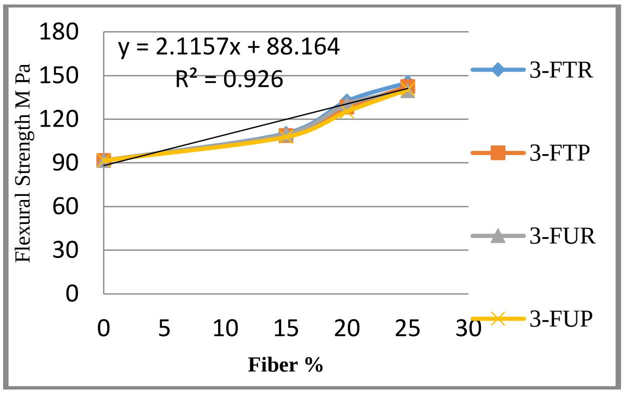
Graph 2 - Mean Tensile Strength for Coarse 3 cm Treated, Untreated, Random and Parallel Orientation of Fiber

Coarse fiber composite sample with treated fiber, 3cm length and random orientation is having the highest tensile strength amongst all the treated and untreated samples given in above graph no. 2 as 68.1 M Pa which is 3.5 times better in 25% fiber volume fraction, for 20% fiber volume strength increases almost 2.5 times and for 15% fiber volume the strength is double as compared to plain resin sheet which is 21.45 M Pa. The results clearly show that with increasing fiber percentage increases tensile strength. The improved strength may be dedicated to the improved surface property and good interfacial bonding between fiber and resin. Very strong correlation is observed between Fiber Vol. Percent and Mean Tensile strength as = 0.983. It can also be observed that there is no significant difference between the samples.

Flexural Strength



Graph 3 – Mean Flexural Strength for Coarse, 3 cm Treated, Untreated, Random and Parallel Orientation of Fiber

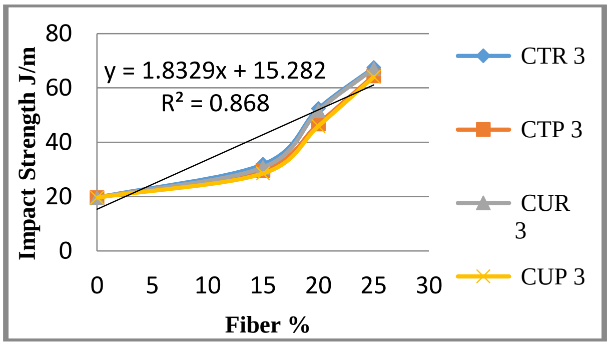


Graph 4 - Mean Flexural Strength for Fine 3 cm Treated, Untreated, Random and Parallel Orientation of Fiber

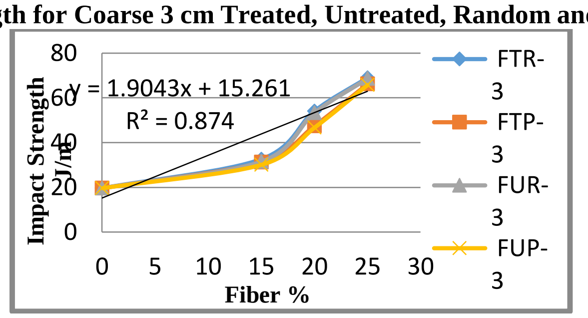
In the flexural testing, the flexural modulus is worked out from the initial close to liner portion of the load extension curve and the maximum composite stress is at point of maximum load. It can be seen that flexural strength of all the Jute reinforced composites is increasing with increasing volume fraction of fiber percent in the composites. The improvement in flexural strength is due to the good interfacial bonding between and contribution of fiber flexibility to the composite. The composite is stronger due to absorption of the resin in the fiber and coating on the surface, hence increases the load bearing capacity of the composite sample. The flexural strength of the FTR-25 composite has 145.2 M Pa is almost 60% better than plain sheet 35% and 20% improvement is also reported respectively in 20% fiber composite and 15% Fiber Composite. There is a strong correlation between the fiber percent in the sample to the Flexural Strength of the composites, the correlation value as 0.910243. The same trend has been observed in all the samples for all the variations i.e., Fiber percentage, fineness, length and orientation

Impact Strength

The impact strength test of the jute-UPR composites at a volume fraction was compared against plain UPR sheet following observations were made



Graph 5 - Mean Impact Strength for Coarse 3 cm Treated, Untreated, Random and Parallel Orientation of Fiber



Graph 6 - Mean Impact Strength for Fine 3 cm Treated, Untreated, Random and Parallel Orientation of Fiber

The impact strength of all the composite samples are given in above graphs no. 9, 10, 11 and 12 from these results it can be said that the impact strength is increasing with increasing volume fraction of the jute fibers, the impact strength of Sample FTR-3 for 25% volume fraction is almost 2.5 times, 20% Volume Fraction is 1.6 times and 15% has 70% better than the plain UPR sheet. The same trend has been observed in all the samples for fiber length and fiber orientation of the fibers in composite samples. We can also see that the fiber treatment do not have any effect on the property. The difference between the samples is not significant for any of the variable. Very strong correlation has been seen within the composite samples with maximum of 0.874344.

IV. Conclusion

In the present study we have observed the following concluding points can be highlighted. The reinforcement of jute fiber in the unsaturated polyester resin have improved the tensile strength by almost 4 times, Flexural Strength 60% and Impact strength 2.5 as compared to plain unsaturated polyester resin sheet. Since impact strength of the composites has also increased to very good level the material will have good scope to be used as engineering/industrial material. It also offers the benefit of low density hence light weight material for applications in automobiles. Reinforcement of Natural fiber in to the unsaturated polyester resin also makes the composite bio-degradable to some extent.

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